THE FRENCH-GERMAN INITIATIVE FOR CHERNOBYL SARCOPHAGUS WASTE MANAGEMENT

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1 INTRODUCTION

Sixteen years after the accident of unit 4 of the Chernobyl NPP the Sarcophagus still remains one of the most dangerous nuclear facilities in the world. The ruin of the destroyed unit 4 and its surrounding Sarcophagus together are termed object Shelter, which still comprises about 96 % of the spent nuclear fuel.

The big amount of irradiated nuclear fuel and radioactive waste may cause potential radiological hazards. Thus, a comprehensive and detailed description of all parameters having influence on the safety state of the Sarcophagus was needed.

At the Vienna Chernobyl Conference in April 1996 Germany and France declared to support the international co-operation of institutions of the Ukraine, Belarus and Russia in view of a solution of the Chernobyl related issues.

The first project identified within the French-German Initiative (FGI) was dedicated to the safety state of the Chernobyl Sarcophagus. This FGI project has been funded by the governments and by the electricity utilities of Germany and France, respectively, with 2 million Euro.

The main aim of the project was to collect, analyse and verify all safety relevant data and to integrate these data in a comprehensive data base. The major fields of investigation were building constructions, systems and equipment, radiological situation, nuclear fuel, radioactive waste and environmental impact /1/.

In this paper in a first step the spent nuclear fuel and the correlating radiological hazards will be described briefly. In the following sections the FGI Sarcophagus project along with some results and practical applications to estimate the radiological risks as well as to support maintenance, waste management and stabilization measures will be presented.

2 SPENT NUCLEAR FUEL AND RADIOLOGICAL HAZARDS

The Sarcophagus was erected in a relatively short time period of several months on the basements of old structures of unknown stability of the former unit 4. Inside the Shelter remained about 96 % of the irradiated nuclear fuel inventory of the reactor of unit 4 before the accident, i.e. 180 t of Uranium of total radioactivity 7 x 10^{17} Bq. However, inspections of the destroyed former reactor vessel after the accident indicated that there was no more fuel inside.

Presently, the spent nuclear fuel exists in four modifications, i.e. radioactive dust in almost all rooms, but predominantly in the central hall, fuel element fragments, mainly in the central hall, molten fuel lava in the lower rooms as well as Uranium and Plutonium solutes in water contained in the lower level. The local distribution of spent nuclear fuel inside the Shelter is shown in Figure 1. The estimated masses of the modifications of spent nuclear fuel are described in Table 1.

The radioactive releases to the industrial site of 500 m radius around the Chernobyl NPP during the first ten days after the accident were estimated to amount 0,5 - 1,0 % of the fuel inventory. After the accident the site was cleaned and decontaminated. Afterwards the ground surface was covered with layers of concrete, sand and gravel. The remaining spent fuel at the Chernobyl Shelter site was estimated on the basis of manual dose rate measurements at ground level and helicopter gamma scanning. Figure 3 shows the assessed distribution of remaining spent fuel. A total amount of about 600 kg with an accuracy of 30 - 50 % resulted.

Recently the potential radiological risks associated with the radioactive fuel containing materials inside the Shelter and the radioactive contamination at the industrial site have been investigated in more detail by GRS in the frame of a research programme sponsored by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety in close co-operation with organizations from Ukraine and Russia /2 - 7/. The results in brief can be summarized in the following manner.

The release of radioactive dust in case of a potential roof collapse causes severe radiation exposures to the workers at the site. The doses due to inhalation and ground shine exceed significantly the annual limits of occupationally exposed persons, i.e. by more than one order of magnitude /2, 3/. However, the exposure drops down with increasing distance, so that at distances of several thousand meters the dose values are very low, e.g. there will be no consequences outside the 30 km zone.

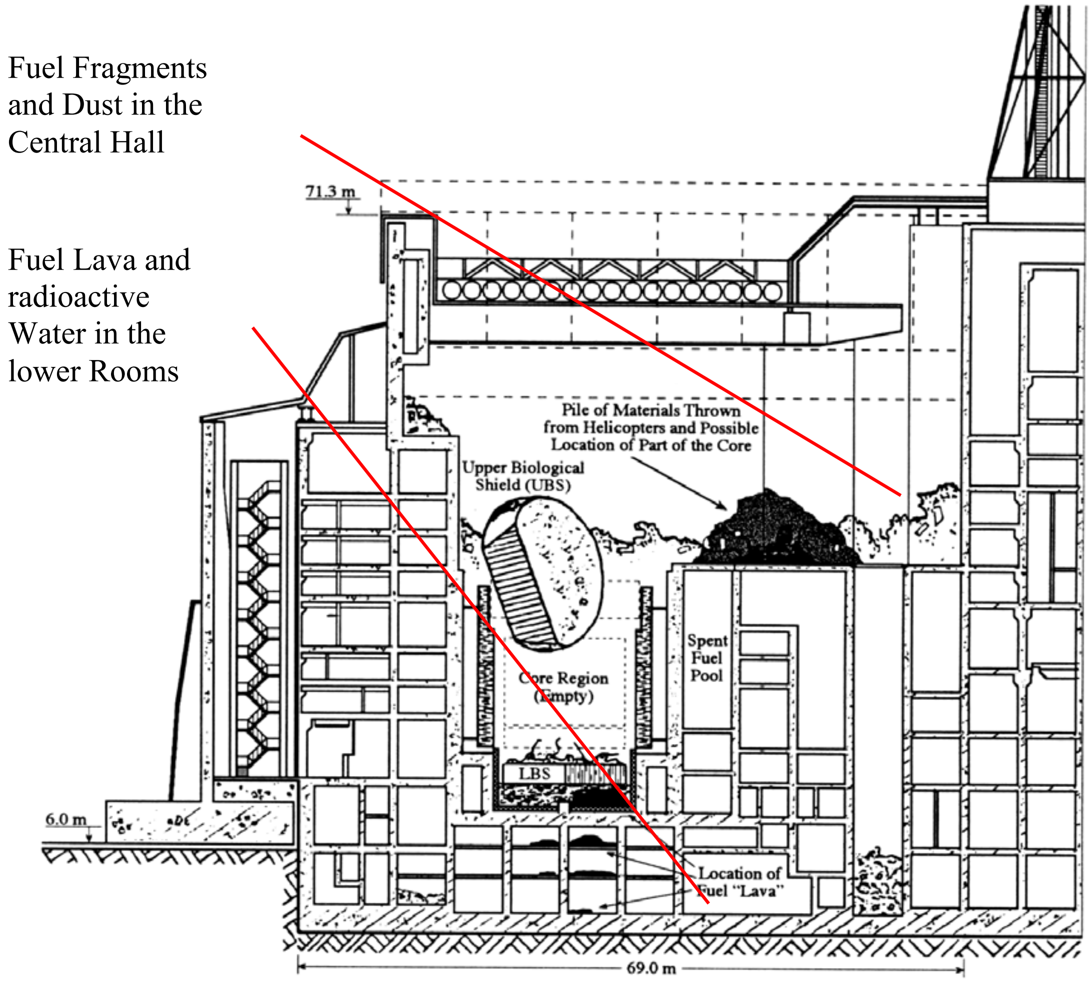

Fig. 1 Scheme of the cross section West-East of the Chernobyl object Shelter

Tab. 1 Remaining fuel inside the object Shelter

Modification	Location	Estimated Mass
Fuel Dust	Central Hall + Upper Rooms	30 t
Fragments of Reactor Core	Central Hall	> 21 t
Fragments of Reactor Core	Southern Cooling Pool	14,8 t
Fragments + Lava + Dust	Upper Rooms + Room 305/2	85 ± 25 t
Lava	Rooms Level 3 (incl. 304/3)	10,5 ± 4,5 t
Lava	Rooms Level 2	12,4 ± 6,2 t
Lava	Lower Rooms	10,5 ± 6 t
Water Solutes	Lower Rooms	4 kg in Water

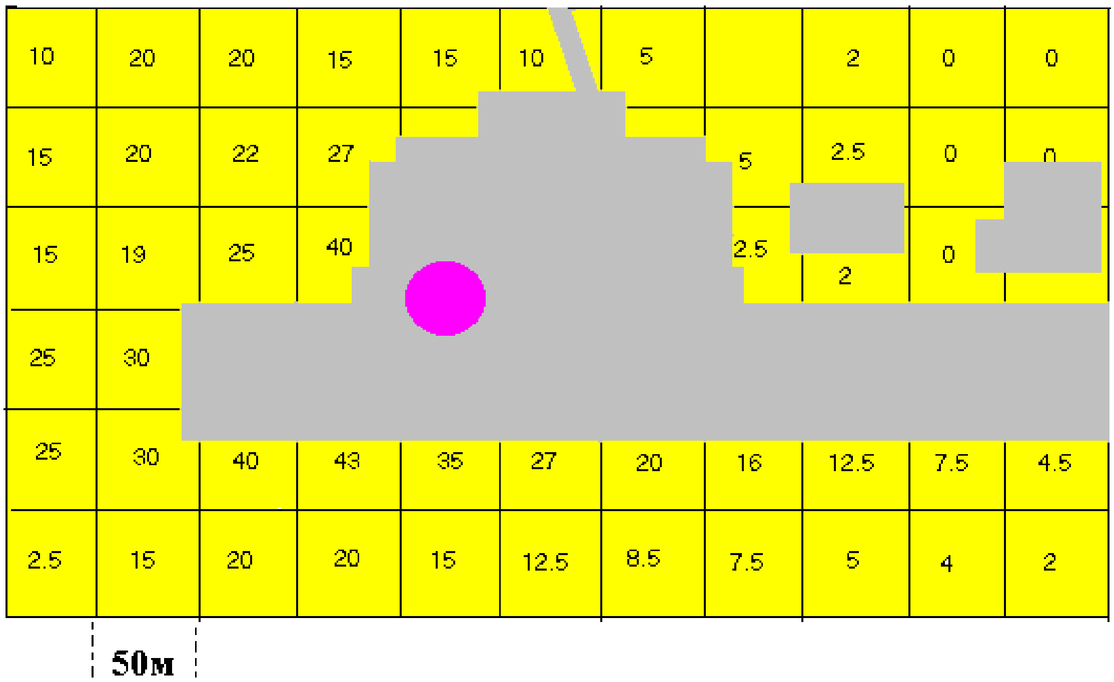

Fig. 3 Distribution of spent fuel fallout at the Shelter site (in kg per 50 x 50 m^2)

Investigating the potential criticality of fuel assemblies in the lower rooms the probability of a hypothetical self sustaining chain reactions would be rather low /4/. Even supposing most pessimistic assumptions the potential consequences, i.e. limited short term release of volatile nuclides and direct radiation, would be screened by the building walls, so that serious radiation exposures to the workers at the site are not to be expected.

2 THE FGI DATA BASE PROJECT

The spent fuel inside the Shelter and the radioactive contamination at the industrial site have an essential impact on all human activities concerned with investigation work, maintenance and stabilization measures which are presently under progress e.g. in the framework of the Shelter Implementation Plan (SIP) because of the radiation exposure.

For planning of any actions towards a stabilization of the unstable building constructions of the Shelter and of measures to retain the radioactive materials inside or to remove outside the Sarcophagus /5/ a unified and comprehensive data base of all safety relevant technical data describing the present safety state of the Shelter is required.

Hence, the main aim of the FGI Shelter project was the collection, analysis and selection as well as verification of all existing safety relevant data of the Shelter and the creation of an appropriate data base.

The project management was carried out by GRS and IRSN on behalf of the German and French governments and utilities. The local project co-ordination in Ukraine was carried out by the Chornobyl Centre which was also the beneficiary of the work. The work was performed by local contractors in Ukraine and Russia.

The main tasks are Building Constructions, Systems and Equipment, Radiological Situation, Fuel Containing Materials and Radioactive Waste and Environmental Impact. In May 1998 the first sub-projects with the local contractors were launched.

For each technical task, in a first step, the main sources of information, i.e. technical documents, publications etc., were identified and described in a bibliography. In the next steps the technical quantities of interest were extracted from theses documents and input into the data base. The input of data was performed by the contractors using especially designed interfaces, which address the kind and the total amount of data for the given task. The development of interfaces, the structure and the configuration of the data base as well as the data integration were subject to a separate contract.

2.1 Contents of Work

The contents of the task „Building Constructions“ was the description of the building constructions before and after the accident. To the parameters considered in this task belong the geometrical dimensions of the rooms, of the walls and of special objects, their properties, e.g. quality of concrete and other building materials, load bearing capacity, order of destruction of walls and other construction elements, newly filled concrete and accessibility of rooms, etc. These data serve as a basis for new projects to reinforce the Sarcophagus. Besides for the reactor building with 956 rooms technical information is also available for all auxiliary buildings.

The task “Systems and Equipment“ contains the description of all systems and equipment installed in the Shelter before and after the accident, i.e. electricity supply systems, water supply and drains, ventilation system, measuring and monitoring systems, etc. The data base contains information on more than 1600 units of systems and equipment.

The task „Radiological Situation“ contains the description of the radiological situation inside the Shelter, i.e. the dose rates of the radiation fields and the radioactive contamination in the rooms of the Shelter. In order to estimate the radiation exposure in advance, when planning work to be carried out by the personnel, these data will be of special interest.

The task „Fuel Containing Materials and Radioactive Waste“ describes the remaining fuel containing materials (FCM) inside the Shelter as shown in Figure 1, the nuclide compositions, the physical and chemical properties etc. These data are very important because of their direct relevance for risk estimates. The data base contains information of about 97 FCM locations.

The task „Environmental Impact“ deals with the description of the influence of the accident to the Shelter site, i.e. the radiation situation above the ground, the contamination and the behaviour of the groundwater, the airborne effluents from the Sarcophagus and the radioactive air contamination at the Shelter site. These data are also of special interest e.g. for planning and preparation of work near the Shelter for stabilization measures etc.

The scope of the task „Data Base Configuration and Data Integration“ is the development of the data base structure, including the bibliography and the contributions of the different technical tasks, described above, as well as the development of a proper technique to retrieve the required information by key words as well as by the help of a GIS navigation system.

2.2 Structure and Features of the Data Base

The data are organized and structured in a data base under Microsoft Access according to the main topics of contents described above. The technical topics are subdivided into objects, e.g. rooms, construction elements, systems, equipment elements, measuring devices, fuel assemblies and fuel debris, pieces of fuel lave, etc., which are generally connected with the corresponding 3D co-ordinates (axis, row and height level). The 3D co-ordinates of the Shelter are prolonged towards the industrial site allowing the description of the environmental impact to the Shelter site in a uniform co-ordinate system.

The states of the objects are described by a text abstracts and by the technical parameters and quantities. Auxiliary data, e.g. graphs, construction drawings, photos, original and animation videos, are also linked with the technical data to facilitate a better understanding.

The main technical quantities contained in the data base are always linked with the corresponding main sources of information described in the bibliography. All data are presented bilingual in English and in Russian using a switch button.

All information available in the data base can generally be retrieved by an optical navigation system based on a Geographic Information System (GIS). For each height level of the Shelter a 2D cross section containing the main objects, e.g. walls, doors, rooms, stairs, main constructions elements, newly filled concrete, fuel containing materials, main systems and equipment, radiation fields, etc. was elaborated.

Analogously, for the Shelter site a 2D cross sections containing data about the elevation levels of the territory, the radiation fields at height levels from 1 m up to 70 m above ground as well as about the groundwater table and the radioactive contamination of the soil and the groundwater was designed.

From the GIS navigator a direct access to all primary and auxiliary data was realized. Selected objects, especially belonging to more than one height level, can also be viewed as 3D images.

4 RESULTS AND APPLICATIONS

In Figure 4 a view from top to the Shelter site is plotted. Along with the reactor building the deaerator and the machinery hall are shown. At the site the radiation exposure rate in 1m height is drawn using a colour spectrum. Also indicated are aspiration units to collect airborne radioactive aerosols as well as bore holes to investigate the ground water /6/. The distribution of the ground water contamination of Sr 90 at the Shelter site is shown in Figure 5.

Figure 6 and 7 demonstrate an application of the data base. Integrating the dose rate over a walk route of personnel inside a room the accumulated dose results. This tool is useful for work planning. Figure 8 shows a typical cross section of the Shelter, where different objects can be viewed and the detailed data can be retrieved.

Figure 9 demonstrate an application of the data base for the erection of the new Shelter 2 which is presently under progress in the frame of the SIP. To build new fundaments at the West of the site e.g. the soil contamination has to be considered /7/.

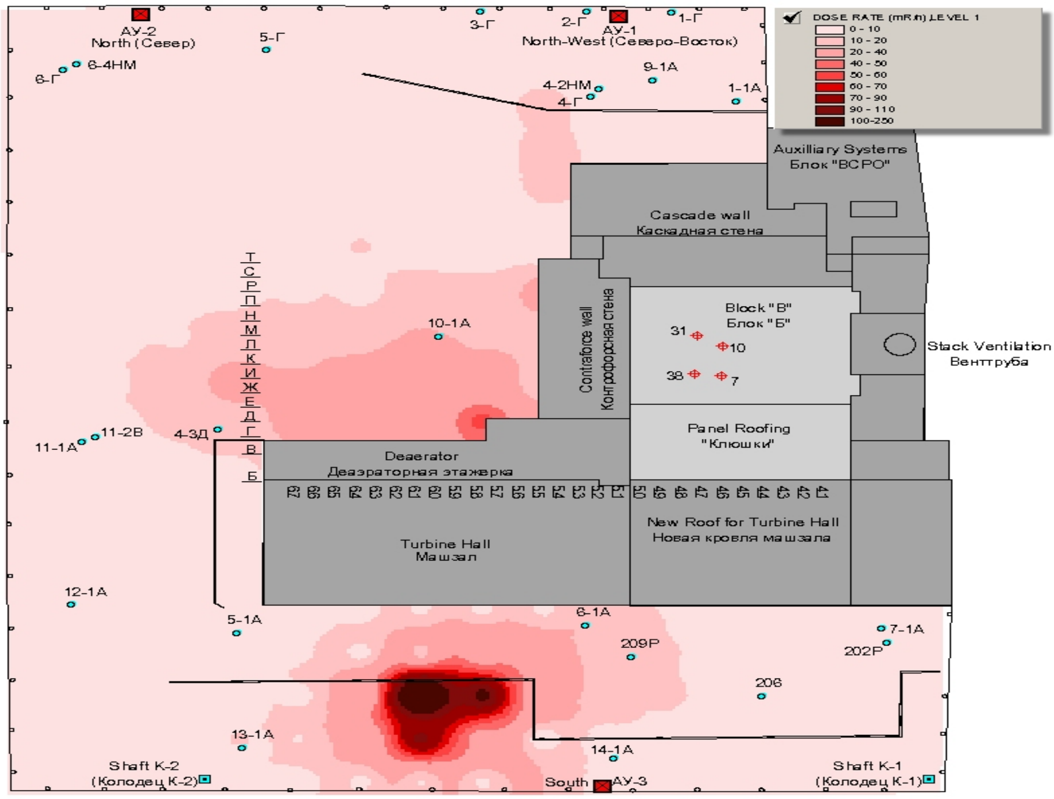

Fig. 4

Dose rate 1 m above ground at the Chernobyl object Shelter site in 2002

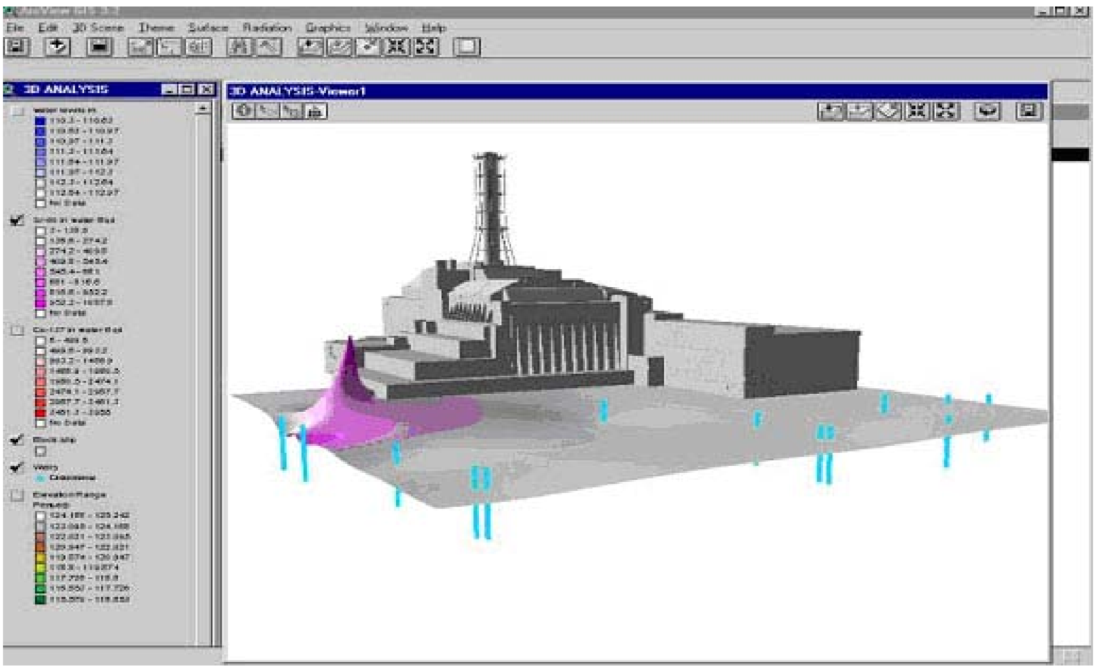

Fig. 5 3D image of ground water concentration of Sr 90 at the Chernobyl Shelter site

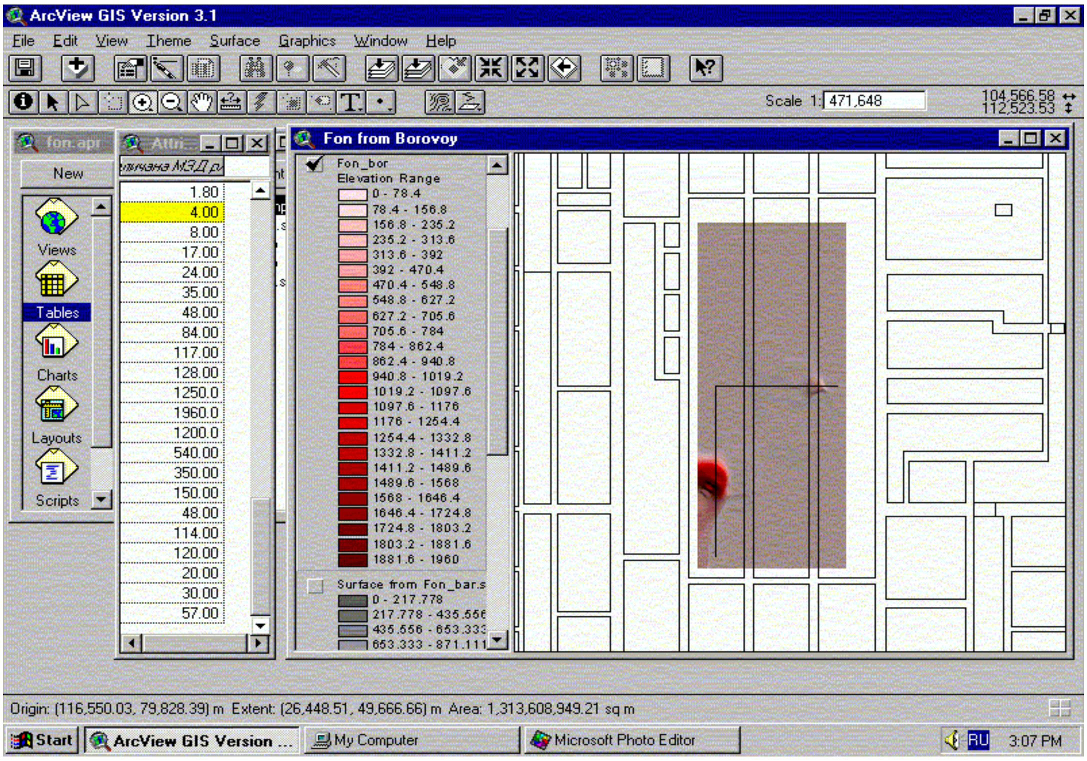

Fig. 6 Dose rate inside a room, walk route across a small and a big contamination spot

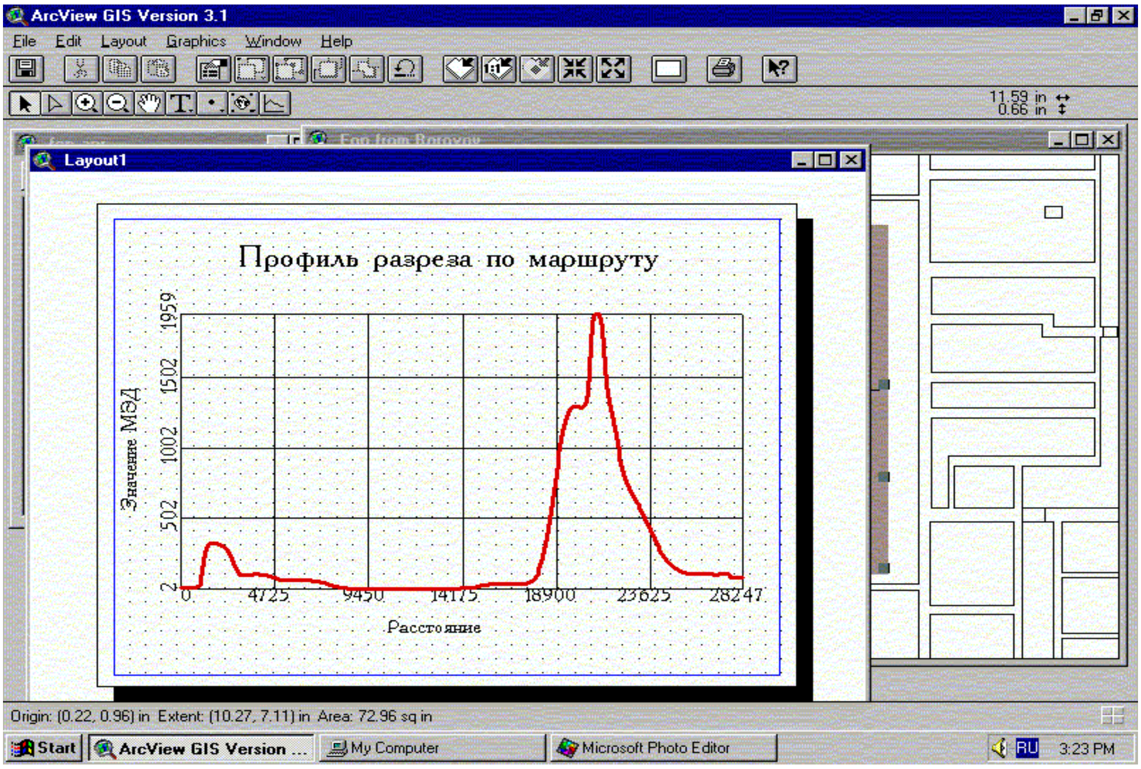

Fig. 7 Dose rate versus distance of walk of personnel along the walk route (see Fig. 6)

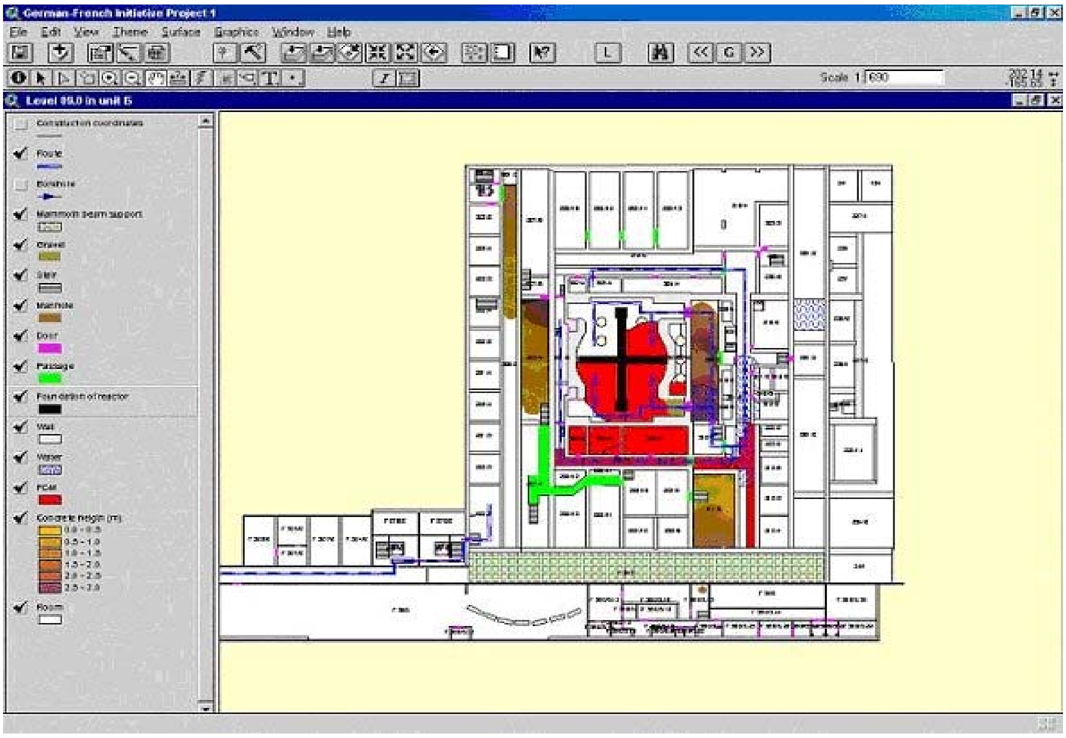

Fig. 8 Cross section of the Chernobyl Shelter at height level 9.00 m with fuel lava (red)

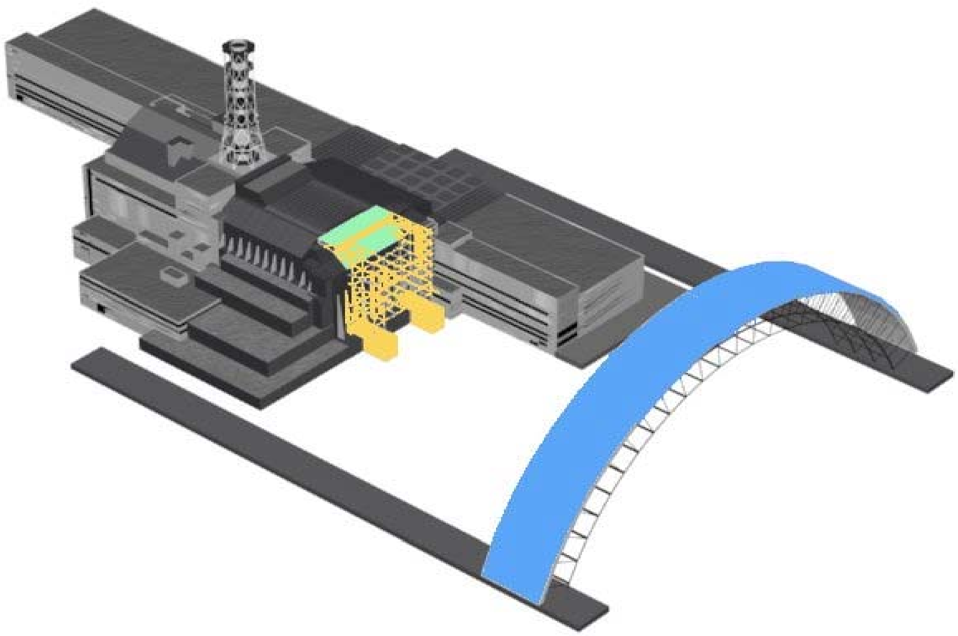

Fig. 9 Principle of the new Shelter 2 erection by shifting arch segments from the West

5 CONCLUSIONS

The FGI Sarcophagus project resulted in a unique data base consisting of detailed information about the safety state of the Shelter. These data will be valuable for estimation of risks, new research work, maintenance, stabilization as well as the erection of the new Shelter 2.

REFERENCES

/1/ G. Pretzsch, V. Lhomme, A. Seleznev and E. Seredynin
"The Chernobyl Sarcophagus Project of the French - German Initiative - Achievements and Prospects",
Twenty Second Annual ESRI International User Conference,
July 08-12, 2002, San Diego, California, U.S.A., paper No 658

/2/ G. Pretzsch
"Radiological Consequences of the Hypothetical Accident "Roof Breakdown" of the Chernobyl Sarcophagus",
Proc. IAEA/EC/WHO Int. Conf. "One Decade after Chernobyl",
Vienna, Austria, April 8-12, 1996,
IAEA-CN-63/415, IAEA-TECDOC-964, pp.591-597, Sept. 1997

/3/ G. Pretzsch, F. Lange, S. Bogatov and A. A. Borovoy
"Radioactive Dust inside the Chernobyl Sarcophagus",
Proc. of Spectrum'98, International Conference on Decommissioning and Decontamination and on Nuclear and Hazardous Waste Management,
Sept 13-18, 1998, Denver, Colorado, U.S.A., Vol. 1, pp. 221-226

/4/ B. Gmal, G. Pretzsch, E. Moser and U. Quade
"Investigation of the Criticality Behaviour of the Fuel Containing Lava Masses inside the Chernobyl Shelter",
Proc. ICNC '99, Sixth International Conference on Nuclear Criticality Safety,
Sept 20-24, 1999, Versailles, France

/5/ G. Pretzsch
"The Chernobyl Sarcophagus Data Base of the German-French Initiative for Robotics Applications",
ANS 9th International Topical Meeting on Robotics and Remote Systems,
March 04-08, 2001, Seattle, Washington, U.S.A.

/6/ G. Pretzsch and S. Bogatov
"Groundwater Contamination at the Chernobyl Shelter Site"
Spectrum 2000, International Conference on Nuclear and Hazardous Waste Management
September 24-28, 2000, Chattanooga, Tennessee, U.S.A. paper No 13

/7/ G. Pretzsch, S. Bogatov and A. Borovoy
"Soil Contamination at the Chernobyl Shelter Site"
Spectrum 2002, International Conference on Nuclear and Hazardous Waste Management
August 04-08, 2002, Reno, Nevada, U.S.A. paper No 54060